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A METHOD OF COMPUTER TESTING OF THE LEVEL OF DEVELOPMENT OF GRAPHIC SKILLS

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ABSTRACT

This paper describes a computer-aided method of testing fine motor skills of the dominant hand and introduces a technique for estimating the level of development of the fine motor skills (using graphical tablet). The paper provides a set of basic parameters that serves as criteria for performance evaluation methodology. The analysis of the tests results is carried out with a computer program that allows determining the level of development of motor skills based on quantitative assessments.

KEYWORDS: Motor Skills, Fine Motor Skills, Dominant Hand, Testing, Graphics Tablet

INTRODUCTION

Currently there are a growing number of people with a range of motor disorders. These motor disorders could have different etiology and pathogenesis, many cases in the. Therefore, the earliest possible diagnosis of the fine motor skills abnormalities is an urgent problem. To solve this problem we need to develop express-evaluation methods which will allow quick and objective examination of the fine motor skills. The application of computer technologies in this type of studies can decrease the role of subjective factors [10]. An ample variety of methods to evaluate the level of the motor skills development are determined by the relationship of fine motor skills with the development of hemispheric specialization and cognitive indicators (speech, memory, attention, logic, etc.). Certain elements of the assessment of the fine motor skills are part of the methods for diagnosis of movement disorders and control of peculiarities of the human neuropsychological development [7].

MATERIALS AND METHODS

In order to evaluate the individual graphic skills of the dominant hand we developed software which implemented on a standard personal computer (PC) with the high-resolution graphics tablet and stylus. We based our research on the work of Leslie J. Coues, Dora W. Chen [4], Mevludin Memedi [5], Diah Norizan Mat, Ismail M., Hamid Putri. M. A., Ahmad S. [6]. The materials for the experiment are referenced in patents for inventions [1, 2 and 3] in the field of psychomotor systems and analysis of motor functions of children and adults.

The hardware part of the graphics skills evaluation system is a standard digital high-resolution graphics tablet- information input device to the computer is a stylus as in figure 1, this specific device enters two dimensional coordinate data to the computer by means of the stylus continuous use of a graphics tablet promotes development of the fine motor skills of the hands. Dealing with a graphics tablet provides by a fine motor hand, because pen navigation is comfortable and ergonomic, hand muscles and arm generally always are relaxed. In general, muscles of the arm and hand

are always relaxed, fingers and palm are moving. The stylus is a natural tool for the human hand, thus navigation and operation with the PC with stylus, it is convenient and accurate. Also, the development of motor skills is influenced by the fact that a graphics tablet is pressure sensitive and the level of pressure applied on the stylus results in thinner or thicker lines drawn by the stylus. Some models of graphics tablets allow the user to draw with fingers.

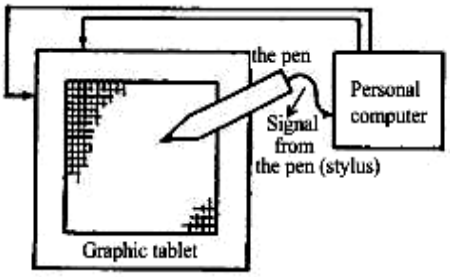

Figure 1: Schematic Showing Operating Principle of Graphics Tablet with Wireless Pen

The studies [8, 9] describe initial results of the assessment of individual characteristics of fine motor skills of the hands (muscle stiffening), graphic skills and tonic movements of the experiment participants. The test was conducted as a challenge before and after writing and considered as a pre-clinical study. In order to increase the objectivivity of the evaluation of fine motor skills development level of the dominant hand each subject of the test was given time to familiarize themsleves with the testing environment, in particular with the graphics tablets and stylus. The first stage of experimental - practical study of motor skills was carried out on the basis of penetration testing of the laboratory sessions during the academic year , among university students fourth and fifth courses. The experiment involved 34 conventionally healthy students (15 female and 19 male) aged 20-23 years. of them 33 student leading hand was right,Only one was left-handed [8, 9].

Each student was tested individually in identical experimental conditions. Graphical tasks were performed individually and technical rules. During the pre-clinical test the following methods were used: inquiring of the student about complaints, observaving, and testing with the software system. Figure 2 shows the required position of the experiment subject during the testing [11]. Each subject was settled in a comfortable position: hands freely located on the table and feet touching the floor. The graphics tablet is located on the flat horizontal surface at the level of subject's elbow. Maintaining a comfortable position during the experiment is an important factor, because it allows adequate determinattion of the quantitative characteristics of dominant hand movements, undistorted by possible tensions caused by uncomfortable position of hands and torso. [10]

Figure 2: The Required Position of the Subject during the Experiment

The subjects of the experiment were surveyed for any complaints that may possibly cause their hand tremor: stress, sleep disorders, prolonged use of drugs, alcohol and narcotic effects, regular physical and psycho-emotional stress on the organism, fractures of the arm bones. During the experiment the following parameters were recorded: how to perform the task, while that recording the speed of performing tests, duration of the experiment, and pressure on the wireless pen.

Each participant of the experiment was recorded into the database including age, sex, dominant hand, and health status.

The experiment includes 20 test templates: drawing straight lines of different lengths with a different angle and spatial orientation. The experiment tests should satisfy the following technical requirements: high contrast color gamut, average (not tiring vision) screen brightness, optimal time to complete one test is one minute. A computer program automatically records the number of templates viewed (A), correctly completed (B), missed (C), and incorrect (D) tests. Based on these parameters we will calculate the accuracy criteria for completing the tests (T) (1) and evaluation of fine motor skills of the dominant hand (p) (2) [10]:

$$T = \frac{A}{A + B + C + D}; \tag{1}$$

$$P = A \cdot T, \tag{2}$$

The lines given are the linear function graph (3) of the form [8]:

$$y = ax + b, \tag{3}$$

Where: x – the independent variable, y – the dependent variable, a – the angular coefficient, b – the shift value of the line.

The deviation of the length of the line drawn by the subject from the reference length; pressure applied to the pen during the drawing was automatically calculated and recorded. The coordinate deviations (4) and (5) of the given lines were represented as a diagrams [8].

$$X = \frac{x \cdot Width}{w}; \tag{4}$$

$$Y = Height - \frac{y \cdot Height}{h}, \tag{5}$$

Where x, y– coordinates of the stylus in the coordinates of the graphics tablet (Bamboo);

w , h – Horizontal and vertical resolution (in pixels) of the graphics tablet (Bamboo);

X , Y – Coordinates of the stylus in the coordinates of a display device;

$Widtl$ – The width of the tablet desktop;

$Height$ – Height of the tablet desktop area.

The line width was calculated as a function of the pressure applied to the stylus.

$$LineWidth = 1 + \frac{pressure}{100}, \quad (6)$$

Where $LineWidth$ –line thickness, a $pressure$ - the pressure applied to the stylus.

Performing tasks on a graphics tablet is a complex coordinated process. It involves a number of factors: general rhythm of the writing hand and working position, vibration innervation of the muscles of the forearm, wrist and fingers, which is very rhythmic and monotonous [8]. For the subjects of the experiment, conducting the tests for a prolonged time caused in muscle fatigue of the dominant hand and synkineses – results of insufficient movements differentiation, that while requested action are included «unnecessary» for it muscles execution [7]. The study of such motor abnormalities is important in the diagnosis of the various disorders of motor activity, and that serve as a prospect of our working.

For this purpose we plan to implement in our software additional testing tool- drawing the Archimedean spiral is the most appropriate graphical object for determining synkineses. At first, the subject will draw the spiral in a clockwise direction (left spiral), then counterclockwise (right spiral), thus carrying out the task of «untwisting» the spiral. Then, in order to detect the fatigue of muscles of the dominant hand it is necessary to «twist» the spiral, as this graphical movement is more difficult, than «untwisting». Also, drawing a spiral twist to the center, this helps to focus attention. The action of untwisting the spiral outside suggests dynamic movement.

The generic Archimedean spiral is defined as a curve r , which is given in polar coordinates by the equation:

$$r = a \cdot \varphi, \quad (7)$$

Where:

a – Displacement along the vector OP (Figure 5b) anticlockwise- right spiral, If displacement in clockwise – left spiral;

φ – Polar angle of vector OP slope to the polar axis. Figure 3 shows the Archimedean spiral in normal condition.

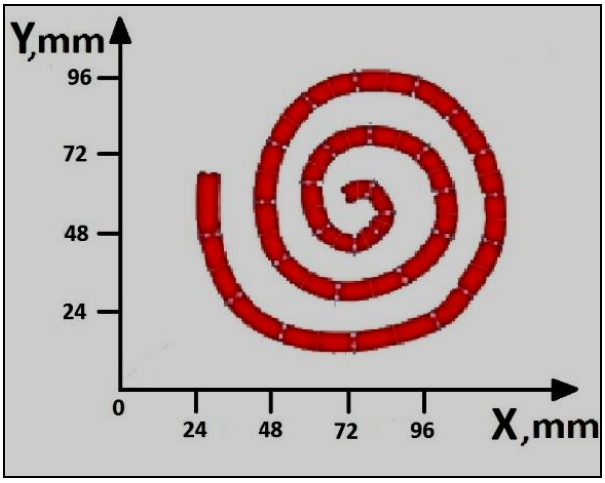

Figure 3: Archimedean Spiral in Normal Condition

THE RESULT OF THE WORK

In order to determine the level of fine motor skills of the dominant hand from the experiment results were evaluated on a number of criteria as (character, length, slope angle, deviation and correct lines drawing), while that recorded the time and accuracy of completing the task.

The results of the first stage of the experiment were compared with each other to establish the reliability of the data and to control the norms of the parameters. While that take into account the result of subjects survey, since 12 subjects of the 34 participants had complaints of various motor skills disorders caused by their lifestyle, which was confirmed by the experiment.

The time allotted to complete one task is one minute. The time spent to draw one line depends on its length. The longer the line the more time it will take the subject to complete the test. During the test eight parameters will be recorded: the time to complete the test, the length of the original and experimental lines, the number of correctly completed tests, the number of tests with some technical inaccuracies, and the number of omitted tests. The pressure force and deviation of the coordinate lines are represented graphically and lines coordinate deviation. On average, it took ten minutes for the experiment subjects to complete all tests, considering that some subjects were very slow in completing the tests.

Figure 4 shows the test results that are the norm for one of the subjects. From the figure we observe that the tests are completed with maximum precision; the pressure on pen is almost the same, which demonstrates a high level of development of graphic skills. This subject completed 18 technically tasks correct and 2 tasks with some inaccuracies. The obtained test results are within norm, as it was confirmed further by our computer calculations.

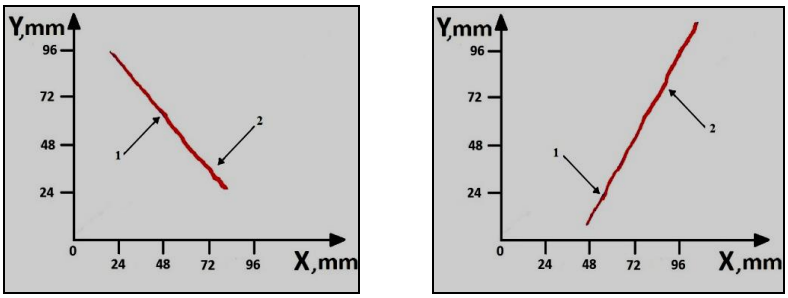

Figure 4: Completed Tasks in the Norm (1 - Original Line, 2 - Experimental Line)

Figure 5 shows the testing results for another subject. In this case we can observe the deviation from the norm. There are incorrectly drawn lines with non-uniform pressure. This subject had been complaining of disorders in motor skills due to his professional activities. This subject completed 8 tasks correctly; 2 tasks with errors and 10 tasks were omitted or left undone.

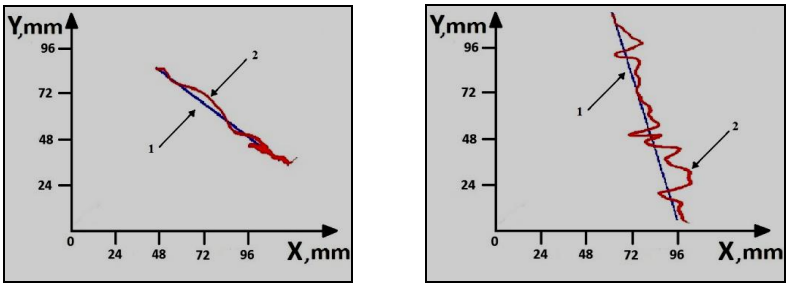

Figure 5: Tasks Completed with the Deviation from the Norm (1 - Original Line, 2 - Experimental Line)

The computer analysis of the parameters of motor activity of the dominant hand allows representative testing data in the form of diagrams. Data visualization in graphical form allows us to identify rules in the dynamics. Figures 6 and 7 show the evaluation of the test results when the subject completed the first six tests. The first diagram shows pressure applied to the wireless pen when drawing, at second and the third diagrams show the deviation of X and Y coordinates of original and experimental lines. Was proposed dataset for sufficient analysis to visualize the general functional of fine motor skills status for human. uncertainties analysis while performing parametric testing made by the subjects during the tests, showed that subjects with disorders of motors skills made similar mistakes. They also demonstrated tension while holding the stylus and slow rate of movements.

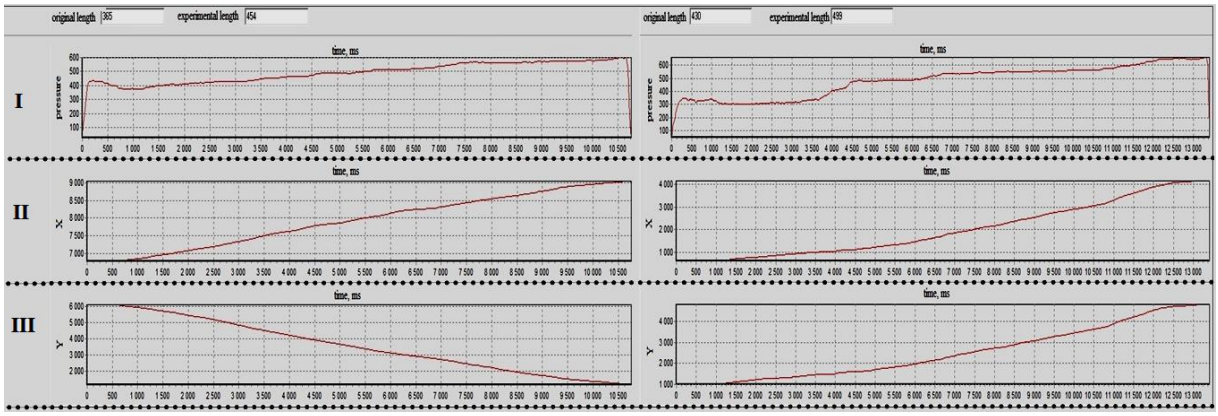

Figure 6: Analysis Showing the Normal Conditions during the Tests

No synkineses were detected during the tests completed by the given subject Figure 6. The subject has no complaints about their health status, which could cause a tremor or other motor skills disorders. As in Figure 6 shows, the pressure on the stylus is light and remains at a certain level and does not vary significantly which indicates the absence of motor skills disorders. The deviation of the coordinates between original and experimental lines had characteristic of monotonously increases or decreases, which is also consider as a normal. The average time to complete one test task is 10.78 seconds; maximum time is 18 seconds; the minimum time is 3.5 seconds. Accuracy is: $T = \frac{20}{20+18+0+2} = 0,5$.

The level of development of fine motor skills is: $P = 20 \cdot 0,5 = 10$, which is considered a high level. Thus, after analyzing all parameters we can conclude that the level of development of fine motor skills in the dominant hand for this subject is high.

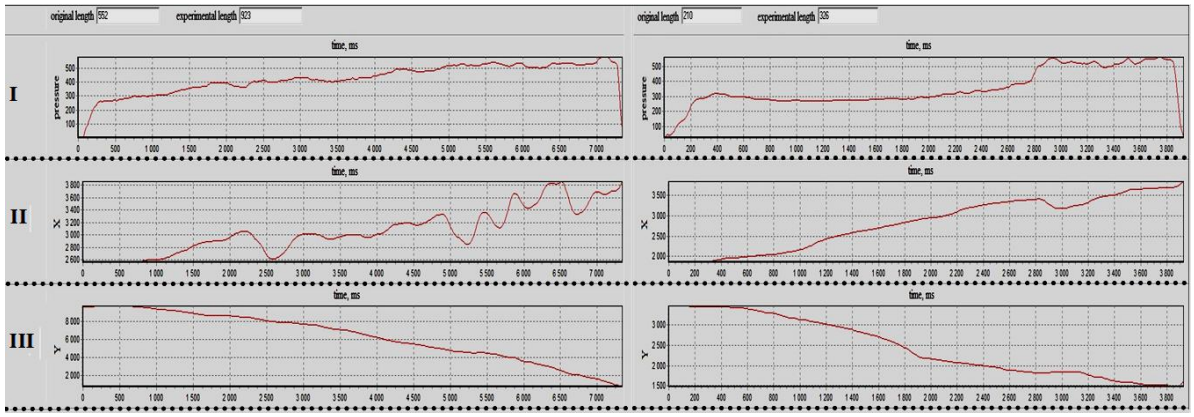

Figure 7: Analysis Showing the Deviation from the Norm during the Tests

The next subject demonstrates synkineses. During the survey the subject was also complaining about their health status due to their professional activities which might cause motor disorders. As Figure 7 shows, the pressure applied to the stylus is nonconstant and it changes irregularly. The deviation of the coordinates between original and experimental lines had characteristic of abruptly decreases or increases which is also considered as a deviation from the norm. The average time to complete one test is 6,36 seconds; the maximum time 14 seconds; the minimum time is 1,1 seconds. After analyzing all the parameters we can conclude that the subject has high level of development of the fine motor skills of the dominant hand. Accuracy of completion of the tasks is: $T = \frac{10}{10+8+10+2} = 0,33$. The development level of fine motor skills is: $P = 10 \cdot 0,33 = 3,3$ which is a low level.

The data of the others participants of the experiment were processed in a similar way. The results are summarized in Figure 8.

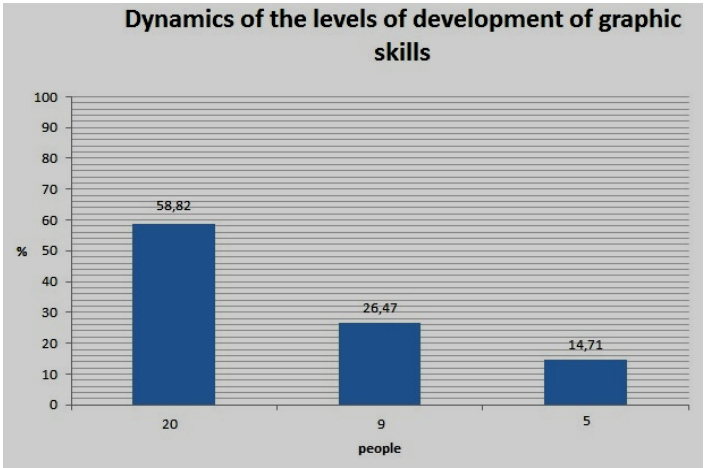

Figure 8: Summary of the Data Analysis for All Participants of the Experiment in Dynamic

The figure shows that 20 subjects have high level of motor skills development, that is (58.82%) from the total number of experiment participants; 9th participant -have medium level (26, 47%), and 5th participant- are at the low level (14.71%). Thus, test results for most of the subjects are within the norm and only five subjects demonstrated abnormalities (tests completed with technical inaccuracies some tests are skipped).

CONCLUSIONS

Based on the experiment results, we can conclude automated analysis method that allows conduction of qualitative and quantitative analysis for individual fine motor skills characteristics baseline on healthy people characteristics, participating in the experiment. In order to conduct the analysis methodlogy was developed specialized software which performs automatic assessment of the fine motor skills in the dominant hand of the subjects.

In the next step of the work, we plan to expand the testing database with the templates for non-linear objects (i.e. Archimedean spiral) that allow to identify muscle fatigue and tremors of the dominant hand. The quality of completing various tests on a graphic tablet comprehensively reflects the functional state of the motor zone of the cortex and hemispheric connections. Thus it can serve as a training simulator for the development or improvement of the level of motor activity. Thus by using specialized software we can detect changes of fine motor skills of the dominant hand and give qualitative estimation of the level of motor skills. Hereafter, when testing several groups of people

(in normal condition, under stress, with various disorders of motor skills) we plan to be able to estimate the diagnostic accuracy (validity) of the proposed method. The comparison of the normal values with the values corresponding to different degrees of deviation allows to estimate the condition of fine motor skills

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